

HELICON PLASMA SYSTEM AND DRY ETCHING METHOD USING THE SAME

Citation 2

Publication number: JP8288259

Publication date: 1996-11-01

Inventor: KADOMURA SHINGO

Applicant: SONY CORP

Classification:

- International: H05H1/46; C23F4/00; H01L21/302; H01L21/3065; H05H1/46;
C23F4/00; H01L21/02; (IPC1-7): H01L21/3065; C23F4/00;
H05H1/46

- European:

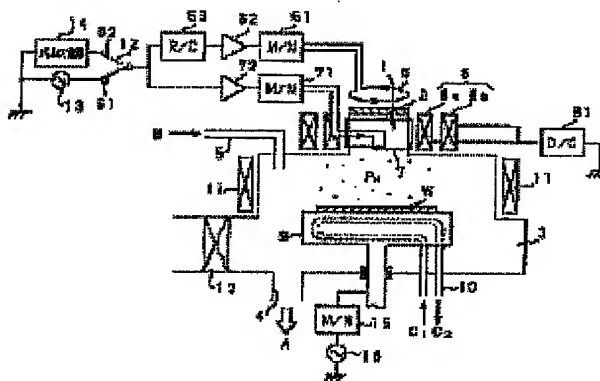
Application number: JP19950092832 19950418

Priority number(s): JP19950092832 19950418

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Abstract of JP8288259

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PATENT ABSTRACTS OF JAPAN

(11)Publication number : 08-288259

(43)Date of publication of application : 01.11.1996

(51)Int. Cl.

H01L 21/3065

C23F 4/00

H05H 1/46

(21)Application number : 07-092832

(71)Applicant : SONY CORP

(22)Date of filing : 18.04.1995

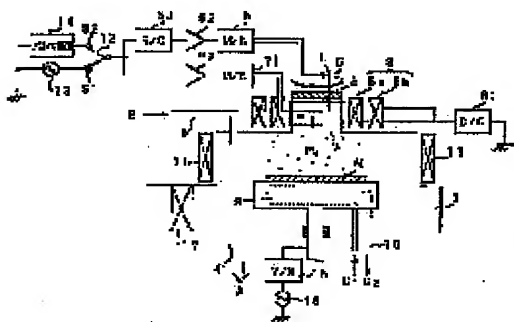
(72)Inventor : KADOMURA SHINGO

(54) HELICON PLASMA SYSTEM AND DRY ETCHING METHOD USING THE SAME

(57)Abstract:

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LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

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CLAIMS**[Claim(s)]**

[Claim 1] The plasma production chamber which consists of dielectric materials, and the 1st antenna for making the interior of said plasma production chamber excite the helicon wave plasma in the $m=0$ mode, The 2nd antenna for making the interior of said plasma production chamber excite the helicon wave plasma in the $m=1$ mode, A RF electric power supply means to supply high-frequency power to said the 1st antenna and said 2nd antenna, Helicon wave plasma equipment which has the diffusion chamber which performs predetermined plasma treatment to the substrate which said plasma production chamber was gone around, connected with the field generation means and said plasma production chamber for making the interior generate a field, and was held in the interior.

[Claim 2] Said RF electric power supply means is helicon wave plasma equipment including the phase adjustment means for shifting mutually the phase of the RF supplied to said the 1st antenna and 2nd antenna according to claim 1.

[Claim 3] Said RF electric power supply means is helicon wave plasma equipment containing the output adjustment device for controlling independently the high-frequency power supplied to said the 1st antenna and 2nd antenna according to claim 1.

[Claim 4] Said RF electric power supply means is helicon wave plasma equipment including the pulse power source which performs intermittently the electric power supply to said the 1st antenna and 2nd antenna according to claim 1.

[Claim 5] Said RF electric power supply means is helicon wave plasma equipment including the RF switching means which changes the electric power supply to said the 1st antenna and 2nd antenna to a high speed according to claim 1.

[Claim 6] Said field generation means is helicon wave plasma equipment including a field switching means to control supply/cutoff of the current over a solenoid coil and this solenoid coil according to claim 1.

[Claim 7] The dry etching approach of performing dry etching to the substrate held in the diffusion chamber connected to this plasma production chamber using the helicon wave plasma equipment which can excite the helicon wave plasma in the $m=0$ mode, and the helicon wave plasma in the $m=1$ mode in a single plasma production chamber.

[Claim 8] Said dry etching is the dry etching approach according to claim 7 performed while exciting simultaneously continuously the helicon wave plasma in said $m=0$ mode, and the helicon wave plasma in the $m=1$ mode.

[Claim 9] Said dry etching is the dry etching approach according to claim 7 performed while exciting simultaneously intermittently the helicon wave plasma in said $m=0$ mode, and the helicon wave plasma in the $m=1$ mode.

[Claim 10] Said dry etching is the dry etching approach according to claim 7 of carrying out by dividing into the just-etching process which etches the etched ingredient film on said substrate by the thickness substantially, and the over etching process which etches a part for the remainder of this etched ingredient film, and changing the generation ratio of the helicon wave plasma in said $m=0$ mode, and the helicon wave plasma in the $m=1$ mode among both processes.

[Claim 11] Said dry etching is the dry etching approach according to claim 7 performed while changing excitation of the helicon wave plasma in the $m=0$ mode, and the helicon wave plasma in the $m=1$ mode to a high speed.

[Claim 12] Said dry etching is the dry etching approach according to claim 7 performed while making a field generate intermittently.

DETAILED DESCRIPTION

*[Detailed Description of the Invention]**[0001]*

[Industrial Application] This invention relates to the equipment and the approach whose achievement of the homogeneity within a field which was excellent about the both sides of an etch rate and substrate residual film thickness also to the wafer of the diameter of macrostomia is enabled about the dry etching approach which used helicon wave plasma equipment and this by making the high density plasma especially with uniform ion density generate.

[0002]

[Description of the Prior Art] In the manufacture field of a semiconductor device, a raise in detailed and high integration are progressing accelerative every year, and room temperature actuation of the transistor of 0.1 micrometers of gate length has also come to be checked on research level. Under such a situation, the demand to the ultra-fine processing technology for manufacturing a semiconductor device is also increasing severity increasingly.

[0003] The dry etching using the plasma generated by the low voltage discharge in gases is a technique indispensable to this micro processing. If the design rule of a semiconductor device is made detailed more than a quarter micron or it from a subhalf micron Since, as for a wafer, sheet processing will be the requisite, rapidity is required of dry etching. Since the ingredient film which constitutes each part of a semiconductor device has thin-film-ized, high selectivity and low damage nature are required. Since a dimension conversion difference with a resist mask is no longer permitted, a high anisotropy is required, and a micro loading effect and generating of particle contamination must also be controlled further. Here, when attaining improvement in the speed, raise in an anisotropy, and low micro loading-ization, the dry etching conditions which weakened radical character and strengthened ionicity are advantageous. The dry etching conditions which weakened stronger ionicity for radical character on the other hand when attaining raise in selection, reduction in a damage, and low contamination-ization are advantageous. However, both these conditions are conditions which conflict mutually, and it is very difficult to set up the dry etching conditions which may satisfy all above-mentioned demands on practical use level.

[0004] Although optimization of these dry etching conditions is usually performed through selection of the class of etching gas, gas pressure, and substrate bias, they are recent years and 1011-/cm³. Some high density plasma sources with which the above ion density is obtained are proposed successively, and selection of the source also serves as an important element.

[0005] The helicon wave plasma indicated by JP,3-68773,A is one of those by which promising ** is carried out also in this high density plasma source. Impress a magnetic field to a cylinder-like chamber and impress high frequency to the loop antenna further wound around this chamber, and accelerate this electron by making a helicon wave generate and conveying energy through the process of Landau damping to an electron from this helicon wave in this chamber, and that generation device makes this electron collide with a gas molecule, and obtains a high ionization rate. With helicon wave plasma equipment, the ion density (an ion current consistency 16-20mA/cm²) of 1011-1013-/cm³ can be about attained under the low voltage of a 10-4Pa base. It is thought that the plasma acquired at this time is in a full dissociation condition mostly.

[0006] And compared with the ECR (electron cyclotron resonance) discharge to which electronic heating is not carried out, it is advantageous only in the limited field in which there is a property that it can spread in comparatively large RF frequency domain between ion cyclotron frequency ω_{ci} and electronic cyclotron frequency ω_{ce} in a helicon wave in, and it is satisfied with this point of resonance conditions.

[0007]

[Problem(s) to be Solved by the Invention] By the way, in manufacture of a semiconductor device in recent years, since it is severe as the demand to dry etching is the above-mentioned, in order to secure the homogeneity of processing, sheet processing must be performed. And since the area of one semiconductor chip is in the inclination which increases with high integration, if economical efficiency and a throughput are taken into consideration, it will become indispensable to use the appearance whose number of the chips which can be cut down from one wafer increases, and the diameter wafer of macrostomia.

[0008] However, diameter-ization of macrostomia has degradation of the homogeneity within the field of etching, and the relation of a front flesh side. For example, since this etching advances with a radical mode subject in the case of the dry etching of aluminum system wiring, in the periphery of a wafer with the large exhaust velocity of a resultant, an etch rate becomes large due to the exhaust stream in a chamber. That is, just etching of aluminum

system ingredient film is early ended like a wafer periphery. On the other hand, the furring film at the time of the dry etching of aluminum system wiring is usually SiO₂. They are insulator layers, such as film. Although etching of this insulator layer advances with the Ion Mohd subject, since ion incidence energy at this time is performed through substrate bias control, it is comparatively excellent in the homogeneity within a field of an etch rate with the equipment of a remote plasma type like helicon wave plasma equipment. Then, in the wafer periphery from which aluminum system ingredient film has been removed early, over etching will be performed too much and the residual film thickness of the insulator layer of a substrate serves as an ununiformity as a result. That is, it is very difficult for etching Mohd to both attain etch uniformity and the homogeneity of residual film thickness on satisfactory level about essentially different aluminum system ingredient film and an essentially different substrate insulator layer.

[0009] Although it is thought that it is effective to change the dissociation condition and saturation ion current consistency of etching gas for example, in just etching and over etching there, with conventional helicon wave plasma equipment, it cannot respond to this request finely. This has the relation with Mohd of a helicon wave excited.

[0010] In free space, in limited space like a plasma production chamber, only specific Mohd is excited and a helicon wave turns into a wave equipped also with electrostatic nature which carries out a circularly-polarized wave in the direction of a right hand, although it is an electromagnetic wave purely. If it deduces from the linearization of the equation of a place, an electric-field pattern as shown in drawing 1 as first 2 Mohd exists. Here, as for drawing of (a), drawing of $m=0$ Mohd and (b) expresses $m=1$ Mohd, and the value of m corresponds to the Bessel function which appears during the expression of electric-field magnification. The pattern currently displayed in the center supports [phase angle $\phi=\pi/2$, and a lower limit] to the phase angle $\phi=0$ among a series of patterns, and upper limit supports phase angle $\phi=-\pi/2$, respectively. From a completely electromagnetic condition [in / at $m=0$ Mohd / in a wave / phase angle $=0$] to a phase angle $=$ it shifts to the completely electrostatic condition in $\pi/2$ spatially. Among both conditions, electric field are spiral and have the property of both electromagnetic [a wave] and electrostatic.

[0011] on the other hand – $m=1$ Mohd – always – electromagnetism – it is mixing of a component and an electrostatic component and an electric-field pattern rotates clockwise simply with wave propagation.

[0012] It is known that the propagating mode of the above-mentioned helicon wave plasma will change in the winding format of the antenna in the outside of a plasma production chamber, and the saturation ion current density distribution in a plasma production chamber also changes with these Mohd. The situation of this change is shown in drawing 2. An axis of abscissa expresses the location (mm) of the diameter direction of a plasma production chamber among drawing, and an axis of ordinate is a saturation ion current consistency (mA/cm²). It expresses. As shown in this drawing, by $m=0$ Mohd, a saturation ion current consistency shows distribution which falls near the center of a chamber and becomes high around it. On the other hand, $m=1$ Mohd shows the pattern which has a peak in the comparatively narrow range of the center of a chamber.

[0013] Since it is designed so that either helicon wave plasma of Mohd of $m=0$ and $m=1$ may be excited, usual helicon wave plasma equipment is difficult for attaining a uniform ion current consistency covering the whole diameter direction of a chamber, also when which Mohd is excited. Moreover, it is also impossible to change in the middle of etching of a saturation ion current consistency.

[0014] This invention solves this above-mentioned trouble, and aims at offering the dry etching approach which makes it possible the helicon wave plasma equipment which can change the dissociation condition and ion current consistency of etching gas free, and to perform uniform etching using this.

[0015]

[Means for Solving the Problem] The plasma production chamber which is proposed in order that the helicon wave plasma equipment of this invention may attain the above-mentioned purpose, and consists of dielectric materials, The 1st antenna for making the interior of said plasma production chamber excite $m=0$ Mohd's helicon wave plasma, The 2nd antenna for making the interior of said plasma production chamber excite $m=1$ Mohd's helicon wave plasma, A RF electric power supply means to supply high-frequency power to said the 1st antenna and said 2nd antenna, It connects with the field generation means and said plasma production chamber for going said plasma production chamber around and making the interior generate a field, and has the diffusion chamber which performs predetermined plasma treatment to the substrate held in the interior.

[0016] As an antenna for exciting the helicon wave plasma of $m=0$ Mohd and $m=1$ Mohd, some types are proposed from before. For example, $m=0$ Mohd's helicon wave plasma can be excited using the double loop

antenna which made the plasma production chamber go around by two loop formations to which only a distance equal to the abbreviation one half of the wavelength of the helicon wave to spread besides the simplest single loop antenna is estranged, and the current of hard flow flows mutually. Moreover, $m=1$ Mohd's helicon wave plasma can excite a plasma production chamber using the half turn antenna which goes around partially. However, in this invention, it is required not to become a failure spatially mutually for the sake of the convenience which installs two antennas near the single plasma production chamber. It is good to install a single loop antenna in the top-plate part of a plasma production chamber, and to install a half turn antenna in the side-attachment-wall section of a plasma production chamber as the 2nd antenna for exciting $m=1$ Mohd's helicon wave plasma as the 1st antenna for following, for example, exciting $m=0$ Mohd's helicon wave plasma.

[0017] The above and said RF electric power supply means may include the phase adjustment means for shifting mutually the phase of the RF supplied to said the 1st antenna and 2nd antenna. Especially this is effective, when the frequency of the RF supplied to both antennas is equal and resonance is prevented. As the above-mentioned phase adjustment means, a relay circuit can be used typically.

[0018] The above-mentioned RF electric power supply means may contain the output adjustment device for controlling independently the high-frequency power supplied to said the 1st antenna and 2nd antenna again. As this output adjustment device, drive amplifier can be used typically.

[0019] The above-mentioned RF electric power supply means may include the pulse power source which performs intermittently the electric power supply to said the 1st antenna and 2nd antenna again. As for the pulse generated according to this power source, that width of face is chosen as the order for 10 microseconds (microsecond). although the relaxation time of this of electron temperature is the order of ns (nanosecond) -- receiving -- the life of the plasma -- the order for dozens of microseconds, and a ***** -- using -- a plasma consistency -- abbreviation -- it is for making only electron temperature fluctuate periodically, maintaining uniformly. Since electron temperature is a parameter which determines the dissociative reaction of etching gas, and the sheath voltage on the front face of a substrate, it becomes controllable [advanced dissociation control or ion energy] according to the above pulse discharges.

[0020] Furthermore, said RF electric power supply means may include the RF switching means which changes the electric power supply to said the 1st antenna and 2nd antenna to a high speed. When performing this change, the $m=0$ Mohd plasma and the $m=1$ Mohd plasma can be made to generate by turns, and the generation ratio of both plasma will be dependent on change timing.

[0021] A thing including a field switching means to control supply/cutoff of the current over a solenoid coil and this solenoid coil as said field generation means can be used.

[0022] Some approaches can be considered for the current supply source to a solenoid coil here, and the effectiveness acquired by this also differs. Although a field does not generate during the cutoff period of the current to a solenoid coil, if the RF is supplied to either [at least] the 1st antenna or the 2nd antenna during this period, not the helicon wave plasma but inductively coupled plasma can be excited. That is, if generation/disappearance cycle of a field exists in the place where high-frequency power is continuously impressed to the antenna, etching which used inductively coupled plasma and the helicon wave plasma by turns will be attained. In addition, since inductively coupled plasma generally has many amounts of radical formation compared with the helicon wave plasma, based on the die length of the current supply source time amount to the above-mentioned solenoid coil, or the duty ratio of current impression, ion / radical formation ratio is controllable to a desired value.

[0023] Or with the helicon wave plasma equipment which is making the plasma production chamber go around with two solenoid coils, an inner circumference side and a periphery side, especially, as the solenoid coil by the side of inner circumference said that propagation of a helicon wave and the solenoid coil by the side of a periphery were used for transportation of the helicon wave plasma, for example, the roles of each coil may differ. In such a case, the current is always impressed, for example to the inner circumference side solenoid coil, and transportation of the helicon wave plasma from a plasma production chamber to a diffusion chamber can also be controlled by controlling supply/cutoff of the current to a periphery side solenoid coil. It enables this to change the consistency of the plasma which can be used near the substrate free.

[0024] On the other hand, the dry etching approach of this invention performs dry etching to the substrate held in the diffusion chamber connected to this plasma production chamber using the helicon wave plasma equipment which can excite $m=0$ Mohd's helicon wave plasma, and $m=1$ Mohd's helicon wave plasma in a single plasma production chamber.

[0025] Said dry etching can be performed as one approach here, exciting simultaneous or intermittently said $m=0$ Mohd's helicon wave plasma, and $m=1$ Mohd's helicon wave plasma.

[0026] If it has an output adjustment device for controlling independently the high-frequency power supplied to the 1st antenna and 2nd antenna as mentioned above at this time and independently controllable helicon wave plasma equipment is used for excitation of these two plasma of Mohd, the generation ratio of both plasma can be adjusted and desired ion current density distribution can be attained in a plasma production chamber.

[0027] Moreover, it can divide into the just-etching process which etches said etched ingredient film for the above-mentioned etching by the thickness substantially, and the over etching process which etches a part for the remainder of this etched ingredient film, and the generation ratio of said $m=0$ Mohd's helicon wave plasma and $m=1$ Mohd's helicon wave plasma can also be changed among both processes. In addition, these two plasma of Mohd hopes that a phase can be shifted mutually, when the frequency of the RF for excitation is equal.

[0028] Although the above is the dry etching approach based on coincidence excitation of the helicon wave plasma of $m=0$ Mohd and $m=1$ Mohd, excitation of both plasma may be changed to a high speed by turns. Between the generate times of each helicon wave plasma at this time, it can adjust so that the ion current density distribution of the request in a plasma production chamber may be attained.

[0029] Furthermore, said dry etching can be performed, making a field generate intermittently. In this case, as mentioned above, inductively coupled plasma and the helicon wave plasma may be excited by turns, ion / radical formation ratio may be controlled, or transportation in the direction of a substrate of the helicon wave plasma may be controlled, and a plasma consistency may be controlled.

[0030]

[Function] The helicon wave plasma of $m=0$ Mohd and $m=1$ Mohd has different saturation ion current density distribution, as shown also in drawing 2. Since the helicon wave plasma equipment of this invention is designed so that both plasma of these can be excited in a single plasma production chamber by having two antennas, the ion current density distribution in this chamber becomes what has both Mohd's character. That is, it becomes possible to compensate depression of the ion current consistency near [in $m=0$ Mohd] the chamber center with the peak in $m=1$ Mohd, and an ion current consistency can be equalized over the large range of the chamber diameter direction as a result. Here, since it is equal to changing independently the height of the peak of two distribution curves of drawing 2, it becomes controllable [more precise ion current density distribution] to control independently the high-frequency power supplied to these two antennas using an output adjustment device.

[0031] furthermore -- if pulse impression of high-frequency power is performed -- control of electron temperature - moreover, if the plasma of $m=0$ and $m=1$ -car Mohd is excited by turns, it becomes controllable [ion / radical formation ratio], and the fine plasma can be controlled according to the contents of desired plasma treatment.

[0032] If dry etching is performed using such helicon wave plasma, compared with the case where the conventional helicon wave plasma equipment which has excited only one of Mohd's helicon wave plasma at once is used, the homogeneity within a field of an etch rate or substrate residual film thickness can be raised remarkably.

[0033]

[Example] Hereafter, the concrete example of this invention is explained.

[0034] By example 1 this example, a single loop antenna is arranged in the top-plate part of a plasma production chamber as the 1st antenna for $m=0$ mode launching, and the example of 1 configuration of the helicon wave plasma etching system which made selectable the interruptible power source which supplies a half turn antenna to a chamber side-attachment-wall side, and supplies high-frequency power to winding and these two antennas as the 2nd antenna for $m=1$ mode launching, and the pulse power source with a switch is explained.

[0035] The notional configuration of this etching system is shown in drawing 3. The plasma production section of this equipment It is the helicon wave plasma PH to the interior. As opposed to the plasma production chamber 1 which consists of dielectric materials for making it generate, and the top plate 2 of this plasma production chamber 1 On an outside, the plasma production chamber 1 is around gone to the pan of the single loop antenna 6 for $m=0$ mode launching formed in parallel, the half turn antenna 7 for $m=1$ mode launching which goes partially the side-attachment-wall side of the same plasma production chamber 1 around, and the above-mentioned half turn antenna 7. Let the solenoid coils 8 which make the field in alignment with the shaft orientations generate be the main components.

[0036] The component of the above-mentioned plasma production chamber 1 was used as the quartz, and the diameter was set to 35cm.

[0037] Although loading of two above-mentioned RF antennas is the greatest special feature of this equipment, both [these] antennas are connected to the common electric power supply network. This electric power supply network includes two kinds of power sources, usual RF generator 13 and the high frequency pulse power source 14, and is made as [choose / with a switch 12 / either]. That is, if the terminal S1 of a switch 12 is chosen and usual RF generator 13 will choose a terminal S2 again, the RF pulse power source 14 will be connected to both antennas. Between the single loop antennas 6, the relay circuit (R/C) 63 as a phase adjustment means, the drive amplifier 62 as an output adjustment device, and the matching network (M/N) 61 for impedance adjustment are connected with the above-mentioned switch 12 in this order. Moreover, between the above-mentioned switch 12 and the half turn antenna 7, the matching network (M/N) 71 is connected with the drive amplifier 72 at this order. In addition, since the above-mentioned relay circuit 63 aims at shifting mutually the phase of the RF supplied to the single loop antenna 6 and a half turn antenna, the illustrated example may be conversely connected to the half turn antenna 7 side. The phase shift by the relay circuit 63 is set as $\pi/2$.

[0038] The above-mentioned solenoid coil 8 is [inner circumference side solenoid coil 8a which is made into double structure and contributes mainly to propagation of a helicon wave, and] mainly the helicon wave plasma PH. It consists of periphery side solenoid coil 8b which contributes to transportation. This solenoid coil is connected to DC power supply (D/C) 81.

[0039] A diffusion chamber 3 is connected to the above-mentioned plasma production chamber 1, the emission field which the above-mentioned solenoid coil 8 forms is met, and it is the helicon wave plasma PH to the interior of this diffusion chamber 3. It is made as [pull]. The side-attachment-wall side and base of a diffusion chamber 3 are constituted using conductive ingredients, such as stainless steel. The interior receives supply of required gas in dry etching from the gas supply line 5 in which high vacuum exhaust air is carried out in the direction of arrow-head A through the exhaust hole 4 by the exhaust system which is not illustrated and by which opening is carried out to the head-lining section in the direction of arrow-head B, and is connected to the load lock chamber which is not further illustrated through a gate valve 17 in the side-attachment-wall side.

[0040] Furthermore, in order to complete the emission field in the about nine above-mentioned wafer stage and to control the electron in the plasma with a chamber wall, and disappearance of active species, the multipole magnet 11 is arranged in the exterior of the above-mentioned diffusion chamber 3 as an auxiliary field generation means. In a diffusion chamber 3, this multipole magnet 11 makes a multi-cusp field generate, and performs plasma confinement. In addition, the arrangement location of this multipole magnet 11 may not be restricted to the example illustrated, for example, may be other locations, such as a perimeter of the stanchion of the wafer stage 9. furthermore, it is -- it is -- this is transposed to a solenoid coil and formation of a mirror magnetic field may be made to perform plasma confinement.

[0041] Furthermore, the conductive wafer stage 9 electrically insulated from that wall surface is held in the interior of a diffusion chamber 3, and it is made as [perform / hold for example the wafer W as a processed substrate, and / on this / predetermined plasma treatment (here dry etching)]. Supply of a refrigerant is received in the above-mentioned wafer stage 9 from the chiller which is not illustrated in order to maintain the wafer W in a process at desired low temperature, and they are an arrow head C1 and C2 about this. The cooling piping 10 for circulating a direction is inserted in. In addition, when controlling the above wafer temperature, it is effective to raise heat conduction between Wafer W and the wafer stage 9, and it is good to use the wafer stage 9 which for that builds in an electrostatic chuck.

[0042] Furthermore, in order to control the energy of the ion which carries out incidence out of the plasma, RF generator 16 for bias impression which impresses substrate bias is connected to Wafer W through the 2nd matching network (M/N) 15 on the above-mentioned wafer stage 9. Here, the frequency of RF generator 16 for bias impression was set to 13.56MHz.

[0043] In example 2 this example, 2 step etching of aluminum system wiring film was performed using the helicon wave plasma etching system mentioned above in the example 1, changing the generation ratio of the $m=0$ Mohd plasma and the $m=1$ Mohd plasma at a just-etching process and an over etching process. The process of this example is explained referring to drawing 6 thru/or drawing 8.

[0044] The important section cross section of the wafer used as an etching sample by this example is shown in drawing 6. This wafer is SiOx. aluminum system wiring film 24 is formed on an interlayer insulation film 20, and the resist mask 25 is further formed with a predetermined pattern on this. Here, as for the above-mentioned aluminum system wiring film 24, the laminating of Ti system barrier metal 21, the aluminum-1%Si film 22, and the TION antireflection film 23 with which the laminating of Ti film and the TiN film was carried out to this order is

carried out one by one.

[0045] Moreover, the above-mentioned resist mask 25 is formed in pattern width of face of 0.35 micrometers through KrF excimer laser lithography for example, using the chemistry multiplier system resist ingredient.

[0046] It set on the wafer stage 9 of the helicon wave plasma equipment which mentioned this wafer above in the example 1, and the terminal S1 of a switch 12 was chosen, and it carried out just etching on condition that the following, having used the above-mentioned aluminum system wiring film 24 as an example.

[0047]

BCl₃ Flow rate 50 SCCM Cl₂ Flow rate 50 SCCM Gas pressure 0.13 Pa Single loop antenna supply voltage 2000 W (13.56 MHz)

Half turn antenna supply voltage 2500 W High frequency bias power 100 W (13.56 MHz)

wafer stage temperature 20 °C – by this just etching, as shown in drawing 7, aluminum system circuit pattern which has an anisotropy configuration was able to be formed mostly. In addition, among drawing, about the ingredient film in which anisotropy processing was carried out by etching, suffix a is attached to the original sign and it has expressed to it. Since etching of aluminum system wiring film advances with a radical Mohd subject, in the periphery of a wafer with the large exhaust velocity of a resultant, an etch rate more nearly usually becomes large due to the exhaust stream in a chamber. However, in this invention, since it was etching where the plasma consistency near the core of a chamber is raised by using together the plasma of $m=0$ Mohd and $m=1$ Mohd, depression of the etch rate in a wafer center section was able to be controlled, and the homogeneity within ±1% of outstanding etching side was able to be attained also on the wafer of the diameter of 8 inch.

[0048] However, as shown in drawing 7, since residual section 24r of aluminum system wiring film which remains a little on a wafer needed to remove, next, it made over etching for it an example, and performed it on condition that the following.

[0049]

BCl₃ Flow rate 50 SCCM Cl₂ Flow rate 50 SCCM Gas pressure 0.13 Pa Single loop antenna supply voltage 2500 W (13.56 MHz)

Half turn antenna supply voltage 2500 W High frequency bias power 60 W (13.56 MHz)

wafer stage temperature 20 °C – as shown in drawing 8, while aluminum system circuit pattern 24a was completed by this over etching, the SiO_x interlayer insulation film 20 of a substrate was etched a little. Since etching of SiO_x advances with the Ion Mohd subject, if the conditions of a radical Mohd subject like [at the time of previous just etching] are continuing, thickness reduction of the SiO_x interlayer insulation film 20 will serve as an ununiformity. However, since the single loop antenna supply voltage by the side of a top plate was increased compared with the time of just etching in this invention and the generation ratio of the $m=0$ Mohd plasma was raised, the high ion current consistency could be obtained to homogeneity, and the homogeneity of film decrease of the SiO_x interlayer insulation film 20 of a substrate was able to be suppressed to ±5%.

[0050] At example 3 this example, the contact hole was etched at one step using the helicon wave plasma etching system mentioned above in the example 1, carrying out coincidence intermittent generation of the $m=0$ Mohd plasma and the $m=1$ Mohd plasma using the RF pulse power source 14.

[0051] The sample wafer used by this example is shown in drawing 8. The laminating of the SiO_x interlayer insulation film 32 with a thickness of about 1.0 micrometers formed of O₂-TEOS plasma CVD is carried out on the Si substrate 30 with which the impurity diffusion field 31 as lower layer wiring was formed beforehand, and, as for this wafer, the resist mask 33 is further formed on it. As for the above-mentioned resist mask 33, the opening 34 with an open aperture of about 0.25 micrometers is formed using a halftone mold phase shift mask.

[0052] By setting in the helicon wave plasma equipment which stated this wafer in the example 1, and choosing the terminal S2 of a switch 12, the RF pulse power source 14 was connected to the single loop antenna 6 and the half turn antenna 7, and the SiO_x interlayer insulation film 32 was etched, supplying the RF from which a phase differs simultaneously intermittently at both antennas. An example of etching conditions is shown below.

[0053]

C-C4F₈ flow rate 50 SCCM CO flow rate 50 SCCM Gas pressure 1.3 Pa Single loop antenna supply voltage 2500 W (13.56 MHz)

Half turn antenna supply voltage 2500 W Switching period 10 μs High frequency bias power 300 W (13.56 MHz)

wafer stage temperature 0 °C – while Above CO draws out O atom in SiO_x according to the reduction operation and accelerating etching here – F* superfluous at the time of over etching It is gas added in order to catch and to

secure the selectivity over the Si substrate 30 of a substrate. . However, in the case of high density plasma like the helicon wave plasma, by the usual continuous discharge, electron temperature goes up too much, CO dissociates to C and O and CO cannot play a desired role. However, in this example, by intermittent impression of a RF, since plasma discharge has lowered electron temperature, making it continue, it can control dissociation of CO to a correct level, and can reconcile improvement in the speed of etching, and high selection-ization. And since it is coincidence excitation of the helicon wave plasma of both $m=0$ Mohd and $m=1$ Mohd, the homogeneity of the plasma is also very high. By the above-mentioned etching, as shown in drawing 10, the contact hole 35 which has a good anisotropy configuration was able to be formed. At this time, the etch rate a part for /and the selection ratio 100 [about] for Si of about 1 micrometer, and **2% of homogeneity within a field were able to be attained.

[0054] Example 4 this example explains helicon wave plasma equipment equipped with the high frequency switching means which changes the electric power supply to the single loop antenna 6 and the half turn antenna 7 to a high speed.

[0055] The notional configuration of this etching system is shown in drawing 4. In addition, explanation is omitted about an intersection with the equipment (see drawing 3) stated in the example 1.

[0056] Unlike the equipment of an example 1, the relay circuit 63 for phase adjustment is not connected to the electric power supply network to the single loop antenna 6, instead, as for this equipment, the high-speed switching circuit 18 is connected to the latter part of usual RF generator 13. This high-speed switching circuit 18 can be switched to the order of a number - 10 microseconds of numbers, and plasma excitation can change that Mohd between $m=0$ and $m=1$, making it continue, and, thereby, can equalize the ion current density distribution of the direction of the diameter of a chamber.

[0057] In example 5 this example, aluminum system wiring film was etched at one step using the helicon wave plasma equipment mentioned above in the example 4. The used sample wafer is the same as what was used in the example 2. An example of etching conditions is shown below.

[0058]

BC13 Flow rate 50 SCCM Cl₂ Flow rate 50 SCCM Gas pressure 0.13 Pa Single loop antenna supply voltage 2500 W (13.56 MHz)

Half turn antenna supply voltage 2500 W High frequency bias power 60 W (13.56 MHz)

High frequency switching period 15 musec Wafer stage temperature In 20 ** this example, etching and the homogeneity within a field of 20 between substrate SiO_x layers which was extremely excellent about both film decreases were able to be attained by using the helicon wave plasma of $m=0$ Mohd and $m=1$ Mohd generated by turns, changing to a high speed.

[0059] Example 6 this example explains the helicon wave plasma equipment which connected the DC power supply to inner circumference side solenoid coil 8a which contributes mainly to propagation of a helicon wave among solenoid coils 8 through the field switching means.

[0060] The notional configuration of this equipment is shown in drawing 5. The high-frequency power supply network of this equipment is what the switch 12 and the pulse power source 14 were abbreviated to from above-mentioned drawing 3, and is made as [carry out / continuation supply of the high frequency from which the phase shifted to the single loop antenna 6 and the half turn antenna 7 mutually].

[0061] On the other hand, in the field generation means, DC power supply (D/C) 81 is connected to inner circumference side solenoid coil 8a which contributes mainly to propagation of a helicon wave through the switch 82.

[0062] The greatest special feature of this equipment is Inductively-coupling PURAZU PI by ON/OFF of a switch 82. Helicon wave plasma PH It is the point which can be excited by turns. That is, since a field does not generate in the plasma production chamber 1 when a switch 82 is set to OFF as shown in drawing 5, and a current is not supplied to inner circumference side solenoid coil 8a from DC power supply (D/C) 81, it is the helicon wave plasma PH. It does not generate but is inductively-coupled-plasma PI to instead of. It generates. On the contrary, when a switch 82 is set to ON and a current is supplied to inner circumference side solenoid coil 8a from DC power supply (D/C) 81, it is the helicon wave plasma PH of $m=0$ Mohd and $m=1$ Mohd in the plasma production chamber 1. It generates. Inductively-coupled-plasma PI Generally a radical consistency is high and it is the helicon wave plasma PH. Since ion density is generally high, if the ON/OFF timing of a switch 82 is optimized with this equipment, desired ion / radical formation ratio can be obtained.

[0063] In example 7 this example, aluminum system wiring film was etched at one step using the helicon wave

plasma equipment mentioned above in the example 6. The sample wafer used here is the same as what was used in the example 2. An example of etching conditions is shown below.

[0064]

BCl₃ Flow rate 50 SCCM Cl₂ Flow rate 50 SCCM Gas pressure 0.13 Pa Single loop antenna supply voltage 2500 W (13.56 MHz)

Half turn antenna supply voltage 2500 W High frequency bias power 60 W (13.56 MHz)

Field switching period 20 msec Wafer stage temperature Although etching of the 20 ^{nm} aluminum system wiring film 24 essentially advanced by radical Mohd, since radical components ran short, sufficient etch rate was not obtained with the conventional helicon wave plasma etching system. On the other hand, at this example, they are the helicon wave plasma and inductively-coupled-plasma PI. Since it was excited by turns, the lack of a radical was suppliable. Moreover, the ion assistant device was able to be operated effectively, harnessing the merit of low voltage discharge of securing the rectilinear-propagation nature of active species and suppressing a microphone good loading effect.

[0065] Consequently, aluminum system circuit pattern 24a which has a good anisotropy configuration as shown in drawing 8 with a quick etch rate called a part for 1.2-micrometer/was able to be formed.

[0066] As mentioned above, although this invention was explained based on the example of seven examples, this invention is not limited to these examples at all, suitably, it can change and the details of the configuration of a sample wafer and the configuration of helicon wave plasma equipment and dry etching conditions can be optimized.

[0067]

[Effect of the Invention] If this invention is applied so that clearly also from the above explanation, with conventional helicon wave plasma equipment, fine tuning of the plasma consistency of the direction of the diameter of a chamber which could not be attained will be attained, and it will become possible to optimize etching conditions finely according to the contents of etching. It can be satisfied with each other who is called control of the rapidity in dry etching, an anisotropy, the homogeneity within a field, substrate selectivity, and a micro loading effect of each conflicting requirement on practical use level with this. Therefore, this invention contributes to high integration of a semiconductor device, high-performance-izing, and high reliance-ization greatly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the mimetic diagram showing the electric-field pattern of the helicon wave plasma in the $m=0$ mode and the $m=1$ mode.

[Drawing 2] It is the graph which shows the saturation ion current density distribution of the helicon wave plasma in the $m=0$ mode and the $m=1$ mode.

[Drawing 3] It is the typical sectional view showing the example of 1 configuration of the helicon wave plasma equipment of this invention in which coincidence continuation / intermittent excitation of the helicon wave plasma in the $m=0$ mode and the $m=1$ mode are possible.

[Drawing 4] It is the typical sectional view showing the example of 1 configuration of the helicon wave plasma equipment of this invention in which mutual excitation of the helicon wave plasma in the $m=0$ mode and the $m=1$ mode is possible.

[Drawing 5] It is the typical sectional view showing the example of 1 configuration of the helicon wave plasma equipment of this invention in which mutual excitation of the helicon wave plasma in the $m=0$ mode and the $m=1$ mode and inductively coupled plasma is possible.

[Drawing 6] In the dry etching of aluminum system wiring film which applied this invention, it is the typical sectional view showing the condition of having formed the resist mask on aluminum system wiring film.

[Drawing 7] It is the typical sectional view showing the condition of having carried out just etching of the aluminum system wiring film of drawing 6.

[Drawing 8] As a result of performing over etching, film decrease of the SiO_x interlayer insulation film of a substrate is the typical sectional view showing the condition of having been generated in homogeneity.

[Drawing 9] In the dry etching of the contact hole which applied this invention, it is the typical sectional view showing the condition of having formed the resist mask on the SiO_x interlayer insulation film.

[Drawing 10] It is the typical sectional view showing the condition of having carried out dry etching of the SiO_x interlayer insulation film of drawing 9 , and having carried out opening of the contact hole.

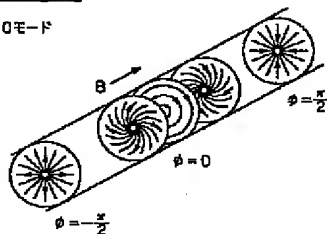
[Description of Notations]

- 1 Plasma Production Chamber
- 3 Diffusion Chamber
- 6 Single Loop Antenna
- 7 Half Turn Antenna
- 8 Solenoid Coil
- 8a Inner circumference side solenoid coil
- 8b Periphery side solenoid coil
- 9 Wafer Stage
- 12 Switch
- 13 RF Generator
- 14 Pulse Power Source
- 15, 61, 71 Matching network
- 16 RF Generator for Bias Impression
- 18 High-speed Switching Circuit
- 62 72 Drive amplifier
- 63 Relay Circuit
- 81 DC Power Supply
- 82 Switch
- 20 32 SiO_x interlayer insulation film
- 24 Aluminum System Wiring Film
- 24a aluminum system circuit pattern
- 25 33 Resist mask
- 35 Contact Hole

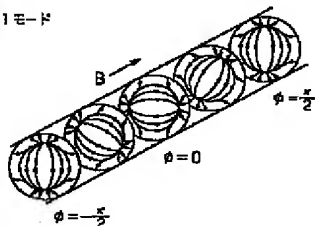
DRAWINGS

[Drawing 1]

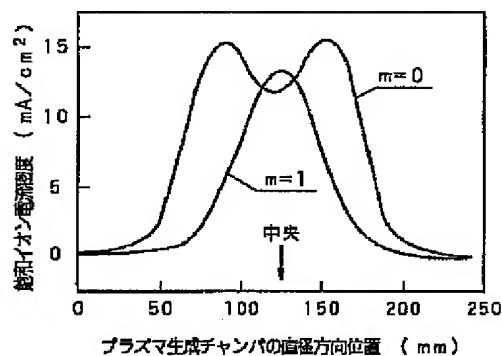
(a) $m=0$ モード



(b) m=1E-7



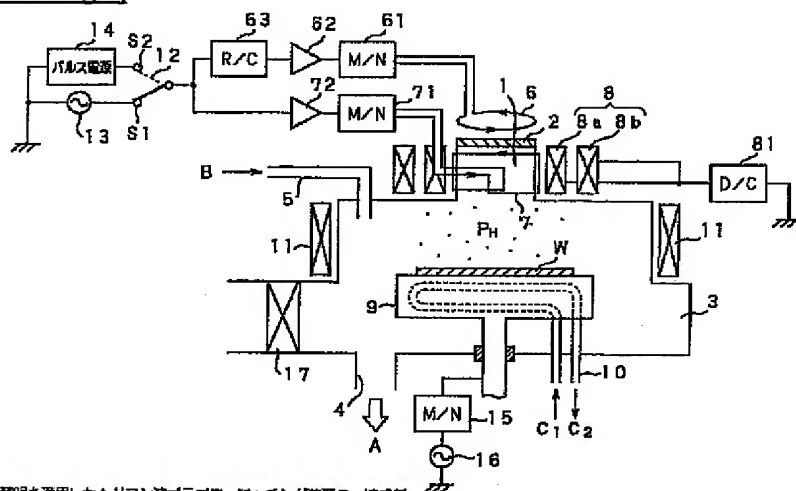
[Drawing 2]



$m=0$ と $m=1$ モードヘリコン波プラズマの飽和イオン電流密度分布の比較

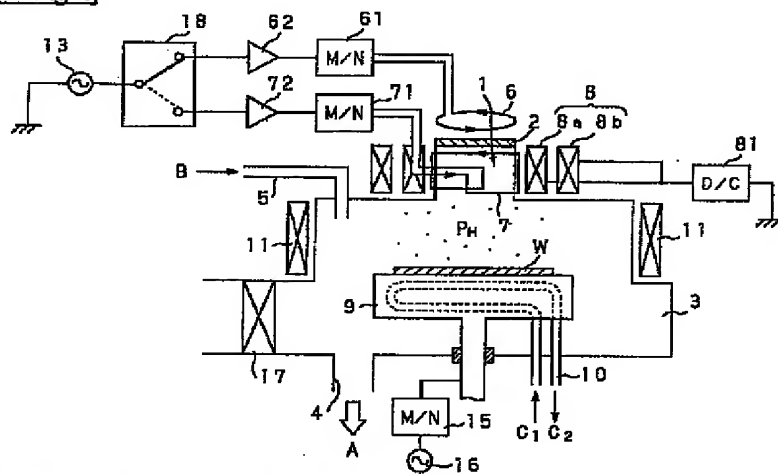
ヘリコン波プラズマの境界パターン

[Drawing 3]



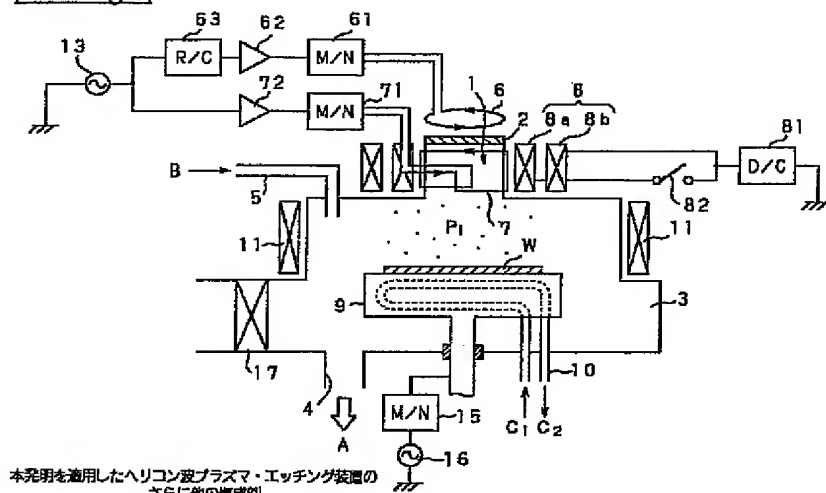
本発明を適用したヘリコン波プラズマ・エッチング装置の一構成例

[Drawing 4]

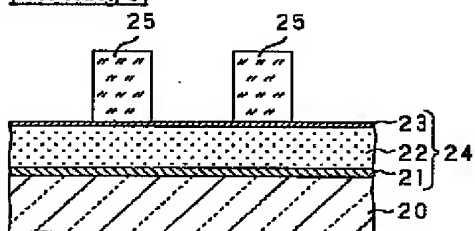


本発明を適用したヘリコン波プラズマ・エッチング装置の他の構成例

[Drawing 5]

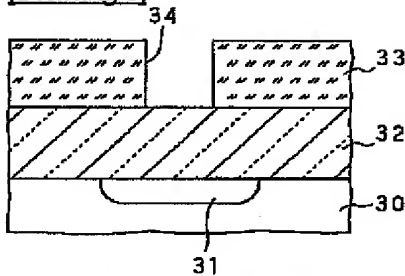


[Drawing 6]



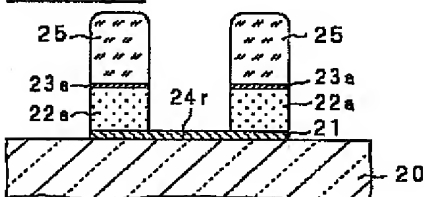
A | 系配膜のエッチング開始前状態

[Drawing 9]



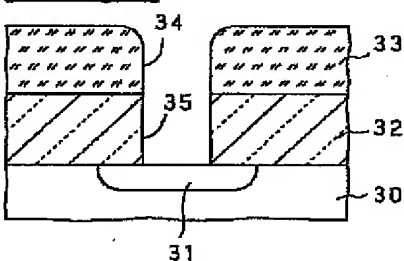
コンタクトホールエッチング開始前状態

[Drawing 7]



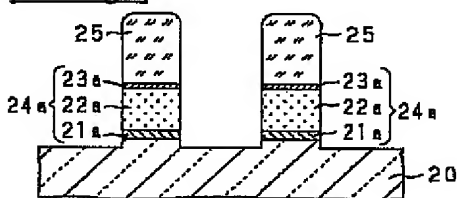
ジャストエッチング終了

[Drawing 10]



エッチング終了

[Drawing 8]



オーバーエッチング終了